REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION.

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
08-01-2012	Abstracts and Oral Presentations	

4. TITLE AND SUBTITLE

Abstracts and Oral Presentations of:
16th Int. Congress of Marine Corrosion & Fouling (ICMCF)
June 24-28, 2012 in Seattle, WA

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Research Laboratory
Oceanography Division
Stennis Space Center, MS 39529-5004

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Office of Naval Research
One Liberty Center
875 North Randolph Street, Suite 1425
Arlington, VA 22203-1995

10. SPONSOR/MONITOR'S ACRONYM(S)

ONR

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release, distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(Include area code)*
Unclassified	Unclassified	Unclassified	UU		

Aluminum Alloy Susceptibility of Sulfide Derivitization

Jason S. Lee

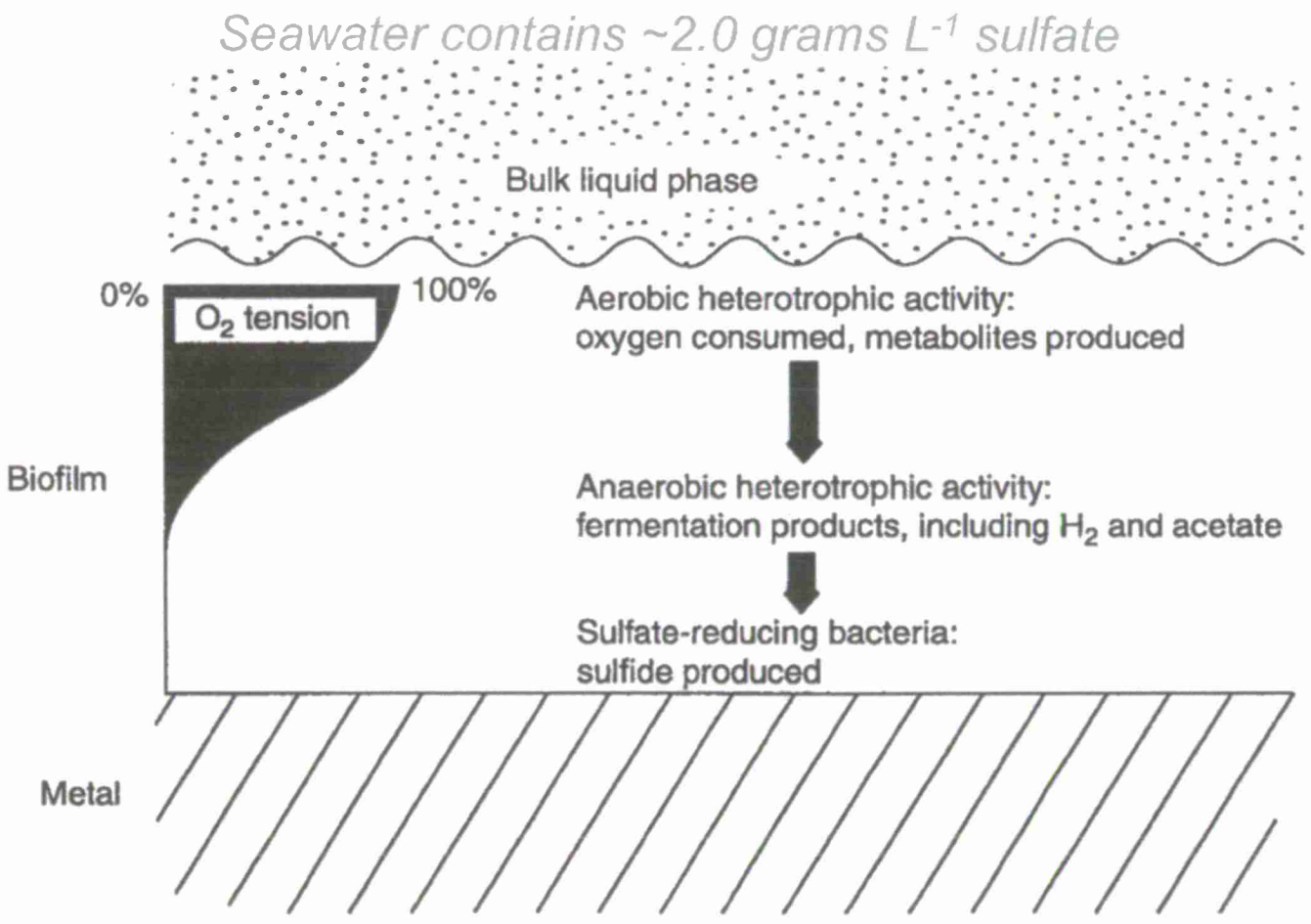
Richard I. Ray

Brenda J. Little

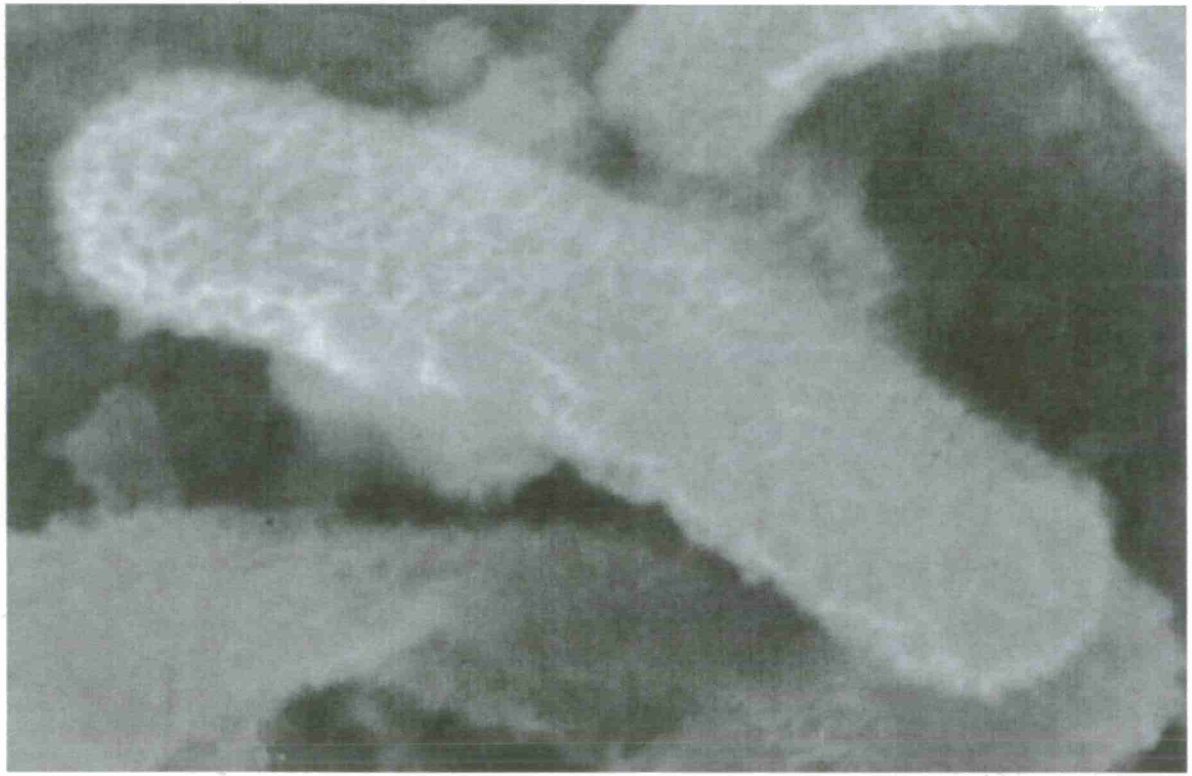
Naval Research Laboratory

Stennis Space Center, MS

Sulfide Derivitization



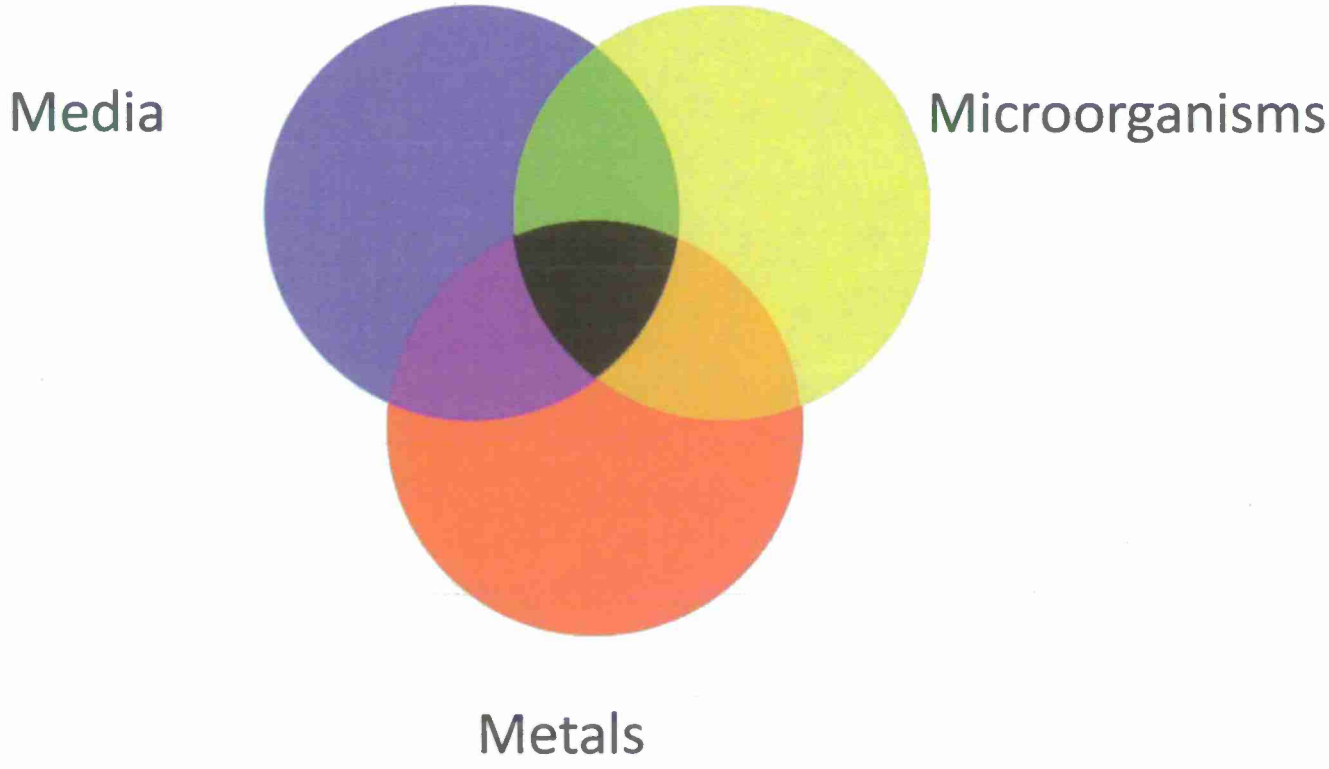
Sulfate-Reducing Bacteria



Initial Seawater Chemistries

Seawaters	pH	Salinity (g/L)	Total Organic Carbon (mg/L)	Sulfate (mg/L)
Key West	7.82	38	1.79	3864
Persian Gulf	7.98	44	1.94	4696

Microbiologically Influenced Corrosion



Scientific Question

Aqueous Corrosion

- Can microbial colonization of aluminum alloys initiate and sustain localized corrosion by sulfide derivitization?

Hypothesis – Sulfate reducing bacteria can derivitize aluminum alloys and produce localized corrosion.

Approach

1. AA in natural seawater (NRLKW & NRLSSC).
2. Characterize corrosion and corrosion products
   - Electrochemistry
   - Microbiology
   - Environmental Scanning Electron Microscopy
   - Transmission Electron Microscopy
   - White Light Profilometry
   - Focused Ion Beam Milling

Principal Aluminum Alloys

1xxx series	minimum 99% aluminum
2xxx series	copper
3xxx series	manganese
4xxx series	silicon
5xxx series	magnesium
6xxx series	magnesium and silicon
7xxx series	zinc
8xxx series	lithium and other elements

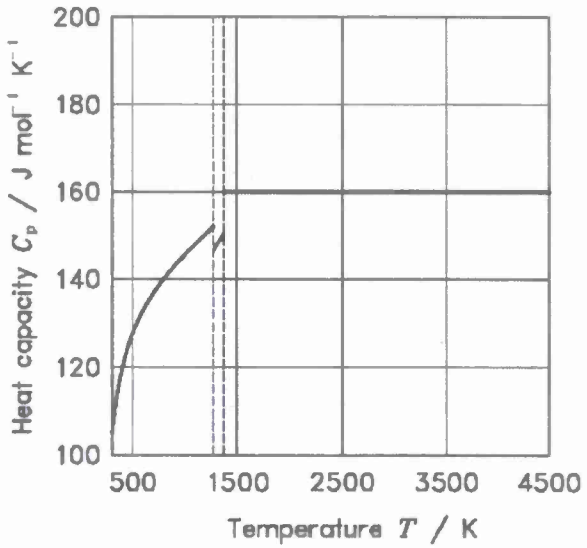
Sulfur Corrosion Products

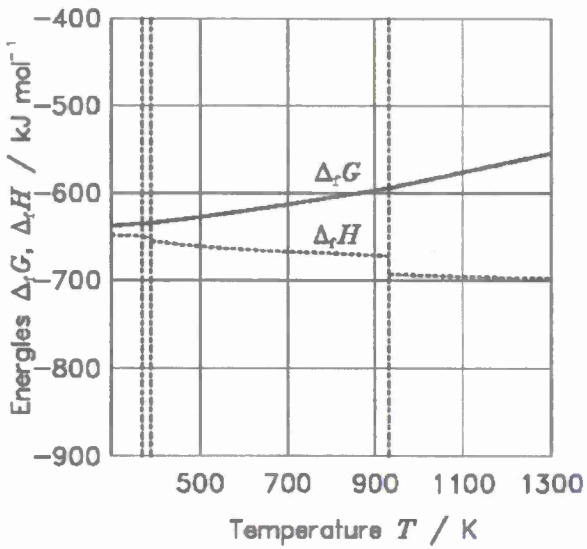
- *Al* - ND
- *Ag* - acanthite (Ag_2S).
- *Ag-Cu alloys* - acanthite, argentite (the high temperature polymorph of Ag_2S or jalpaite (Ag_3CuS_2)).
- *Cu* - complex suites of sulfide minerals: the most common product is chalcocite (Cu_2S). Final product in many cases is blue-remaining covellite (CuS_{1+x}).
- *Cu-Ni alloys* - Sulfide corrosion products similar to those of Cu but with significant djurleite ($Cu_{31}S_{16}$). No Ni minerals observed.
- *Cu-Sn alloys* - Corrosion products similar to those in Cu.
- *Fe (carbon steel)* - Final product is pyrite (FeS) with numerous intermediates.
- *Fe (stainless alloys)* - Rates are slower than pure Fe or carbon steel. No Ni minerals have been detected. Stainless steels with 6% or more Mo appear to be very resistant.
- *Mg* - ND
- *Ni* - millerite (NiS).
- *Pb* - galena (PbS).
- Zn – sphalerite (ZnS)

Al-S: Thermodynamics

Al_2S_3 (Aluminium Sulphide) [94SGTE]

T	$S°$	$H°_{298} - H°_0$	$\Delta_f H°$	$\Delta_f S°$	$\Delta_f G°$	$\Delta_{trs} H°$	$\Delta_{trs} S°$	type
298.15	116.860	18632.0	–648500.0	–35.950	–637782.0			
1273.0						0.0	0.000	$S \rightarrow S$
1373.0						66000.0	48.070	$S \rightarrow L$

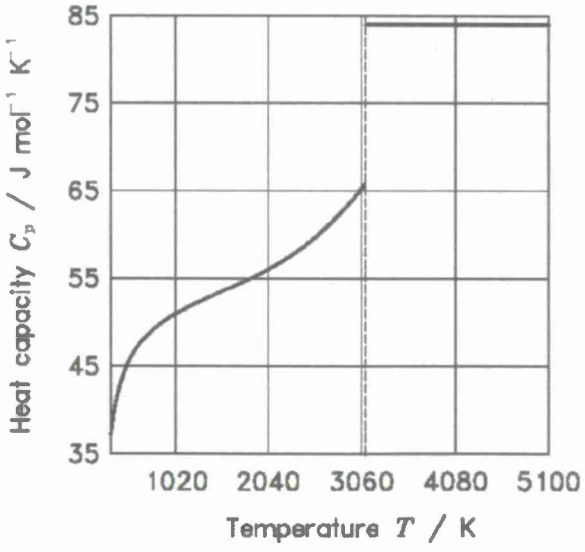


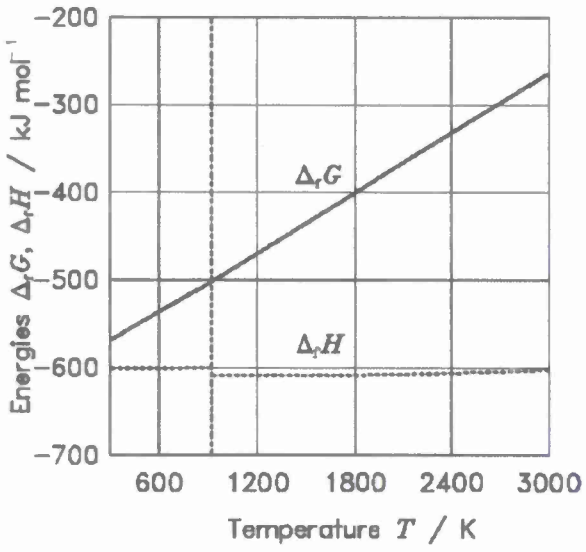


Mg-O: Thermodynamics

MgO (Magnesium Oxide) [94TCRAS]

T	S°	$H^\circ_{298} - H^\circ_0$	$\Delta_f H^\circ$	$\Delta_f S^\circ$	$\Delta_f G^\circ$	$\Delta_{trs} H^\circ$	$\Delta_{trs} S^\circ$	type
298.15	26.95	5160.0	–601600.0	–108.295	–569312.0			
3100.00						77000.0	24.839	$S \rightarrow L$

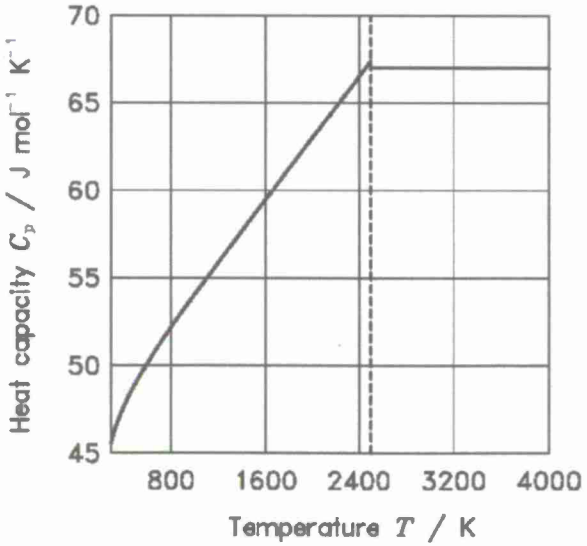


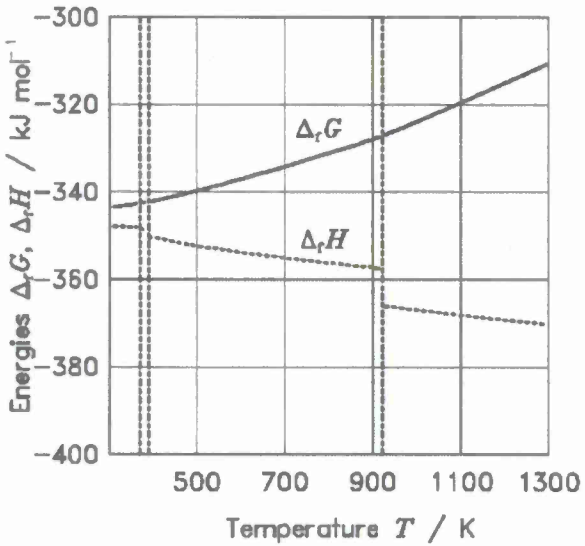


Mg-S: Thermodynamics

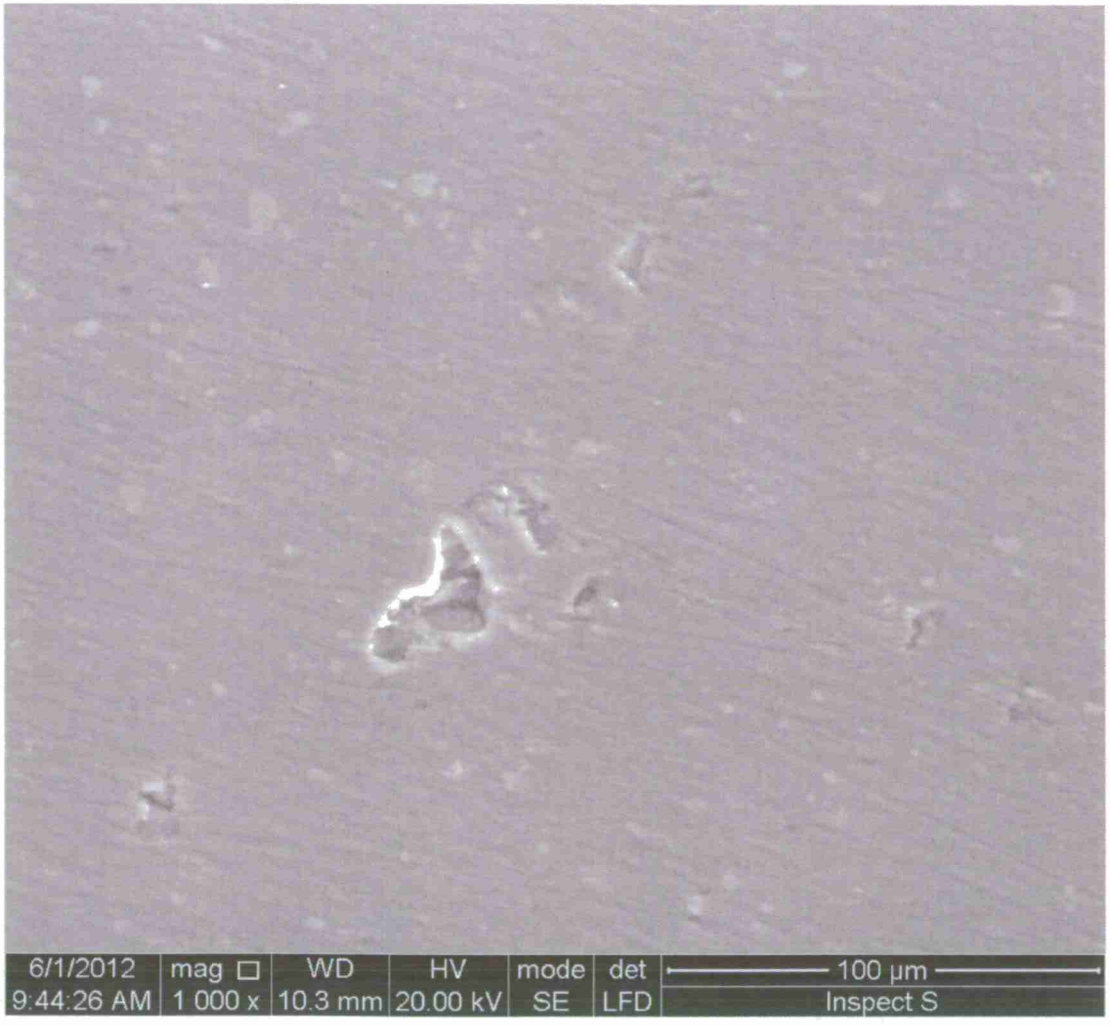
MgS (Magnesium Sulphide) [94TCRAS]

T	S°	$H^\circ_{298} - H^\circ_0$	$\Delta_f H^\circ$	$\Delta_f S^\circ$	$\Delta_f G^\circ$	$\Delta_{trs} H^\circ$	$\Delta_{trs} S^\circ$	type
298.15	50.330	8330.0	–348000.0	–14.411	–343703.0			
2500.00						63000.0	25.200	$S \rightarrow L$

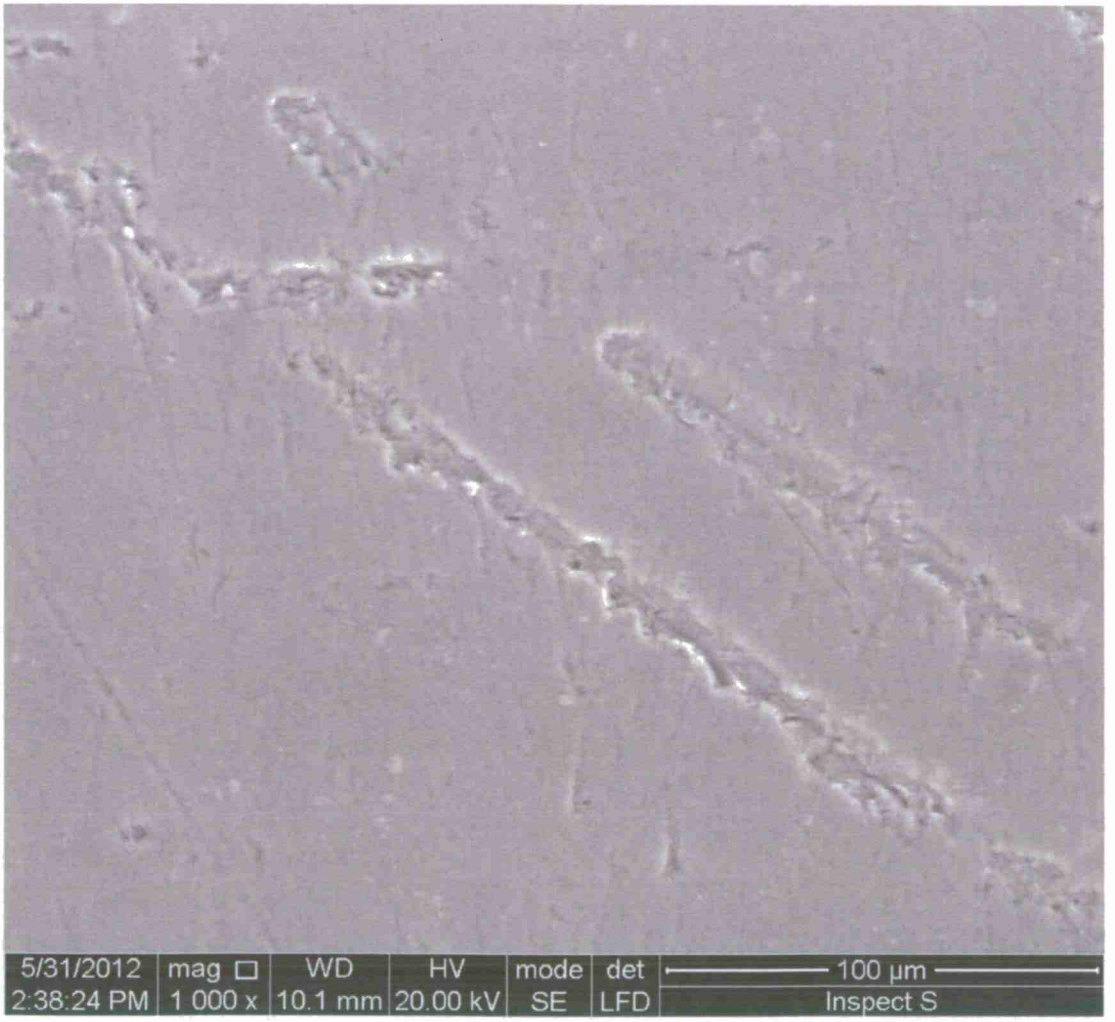




5083


6/1/2012
9:44:26 AM
mag
1 000 x
WD
10.3 mm
HV
20.00 kV
mode
SE
det
LFD
100 µm
Inspect S

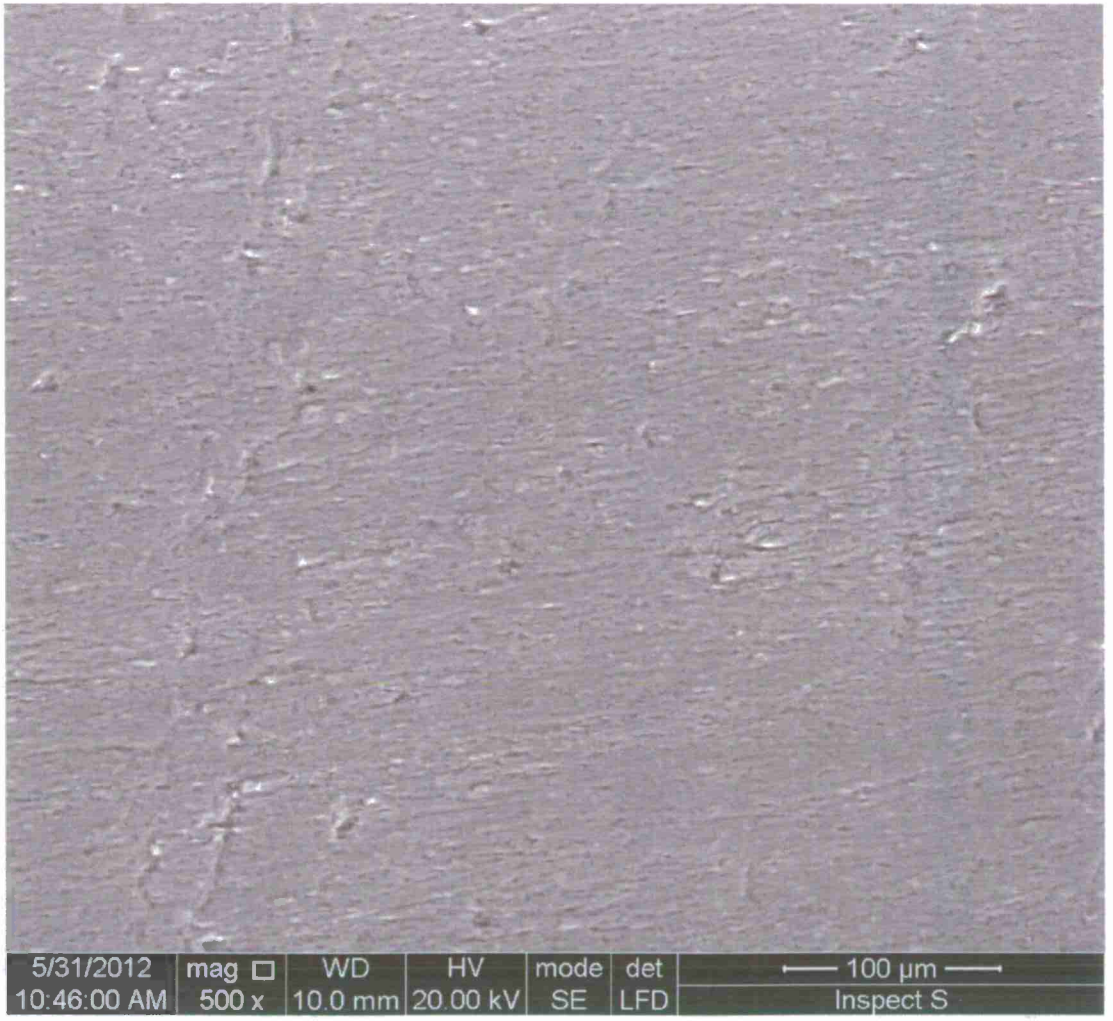
5052


5/31/2012
2:38:24 PM
mag
1 000 x
WD
10.1 mm
HV
20.00 kV
mode
SE
det
LFD
100 µm
Inspect S

4047


5/31/2012
1:36:50 PM
mag
1 000 x
WD
10.0 mm
HV
20.00 kV
mode
SE
det
LFD
100 µm
Inspect S

3003


5/31/2012
10:46:00 AM
mag
500 x
WD
10.0 mm
HV
20.00 kV
mode
SE
det
LFD
100 µm
Inspect S

We know the following:

- 5xxx Al used above and below the waterline:

Alloys	Platforms
5083	Landing Craft Air Cushion (LCAC)
5086	Littoral Combat Ship (LCS)
5456	Legacy platforms
5745	

- Corrosion problems occur above and below the waterline:
  - Pitting, cracking, crevice corrosion